

1 DOWNHOLE APPARATUS FOR MOBILISING DRILL CUTTINGS

2

3 The present invention relates to apparatus for
4 mobilising drill cuttings in an oil or gas well.

5

6 The art of drilling wellbores for recovery of oil
7 and gas is well known. One particular problem faced
8 by this art is the removal of cuttings from the well
9 as they are generated by the action of the drill bit
10 cutting into the formation. The cuttings need to be
11 removed from the bit and conveyed back to surface as
12 efficiently as possible, as their persistence in the
13 wellbore hampers drilling activity, and tends to
14 reduce the productivity of the well.

15

16 Cuttings are washed back to surface by drilling mud
17 or fluid pumped down the string, out through the
18 bit, and back up the annulus surrounding the string.
19 This solution is generally satisfactory, but in long
20 and deviated wells we have found that cuttings still
21 tend to clump and impede the drilling activity, or
22 the production of the well.

1 According to the present invention there is provided
2 apparatus for mobilising drill cuttings in a well,
3 the apparatus comprising at least one vane, and two
4 or more blades defining at least one fluid conduit
5 between adjacent blades, the blades and vane being
6 rotatable relative to one another.

7
8 Typically the blades are configured to create a
9 pressure difference in fluid flowing through the
10 conduit, but this is not essential, and a fluid
11 drop, if required, can be induced by other means
12 apart from the blades.

13
14 The apparatus typically comprises a sleeve or
15 collar, which is typically tubular and is adapted to
16 fit over a string in the well. The string can be a
17 tubing string, drill string, or casing string etc.
18 Typically the vanes are provided on the sleeve.

19
20 Typically the blades are mounted on a bushing that
21 is rotatably mounted on the sleeve.

22
23 However, in certain simple embodiments, it is
24 sufficient to provide the vanes direct on the tubing
25 string (or on a sleeve attached to the string) and
26 to provide the blades on an adjacent part of the
27 string, or on a separate sleeve attached thereto, so
28 that the blade-bearing bushing is not directly
29 attached to the vane-bearing sleeve. The blades or
30 the bushing can optionally be incorporated into a
31 sub in the string, or on a collar that is separately
32 attached to the string.

1 Typically the sleeve is adapted for attachment to a
2 drill string, and the fixing means typically
3 comprises a clamp means such as an annular clamp to
4 fix the sleeve over the outer surface of the drill
5 pipe. However, the sleeve may equally attach to
6 casing or any other oilfield tubular goods.

7
8 The vanes can be carried direct on the sleeve, or in
9 some embodiments can be provided on a separate
10 bushing rotationally (or otherwise) affixed to the
11 sleeve. The vanes typically rotate with the drill
12 string in normal rotary drilling operations as they
13 are typically rotationally fixed to the drill
14 string. The rotation of the vanes agitates the
15 fluid surrounding the apparatus, and creates thrust
16 tending to drive the fluid past the sleeve.
17 The blades of the bushing typically create a
18 pressure drop in the fluid as it flows past the
19 apparatus, driven by the rotation of the vane(s).

20
21 Typically the bushing is free to rotate relative to
22 the sleeve, which is affixed to the drill string.
23 Thus, upon rotation of the drill string (or casing)
24 during normal rotary drilling, the bushing typically
25 remains stationary relative to the wellbore, while
26 the drill string rotates.

27
28 Typically the blades on the bushing project radially
29 outward to a greater extent than the vanes of the
30 sleeve, so that the radially outermost surface of
31 the blades contacts the inner surface of the bore
32 within which the string is located, and this

1 centralises the sleeve within the bore. In
2 preferred embodiments, the vanes are radially lower
3 than the blades, and can freely rotate within the
4 bore, as the higher blades provide a stand off
5 against the inner surface of the bore. The bore can
6 be the unlined wellbore, or can be the bore of
7 casing, liner or other tubing in which the apparatus
8 is located.

9
10 The blades can be set parallel to the axis, or can
11 be offset with respect to it, so that they extend
12 helically around the bushing. In some embodiments
13 the blades are offset at an angle of 3-10° e.g. 5°
14 from top left to bottom right with respect to the
15 axis of the bushing. This orientation is useful in
16 drillstrings that are conventionally rotated to the
17 right, as the fluid path up the annulus tends to
18 flow in a spiral from bottom right to top left at
19 around 5° off the axis. Therefore, the offset
20 blades do not substantially impede the fluid flow
21 rate. Clearly adjustments can be made to the offset
22 angle to suit the fluid flow direction in other
23 wells.

24
25 The blades typically have an asymmetric profile, and
26 in preferred embodiments the blades are shaped in
27 the form of foils, so that the fluid conduits
28 defined between adjacent blades on the bushing
29 change in profile. Typically the fluid conduits are
30 relatively narrow at a lower end (nearest the drill
31 bit) and grow relatively wider toward the upper end
32 (furthest away from the bit). The increase in

1 dimension from the bottom of the channel to the top
2 causes a pressure drop in the fluid flowing through
3 the channel.

4

5 The blades can have profiled cross sections (i.e.
6 end-on view) in the form of an hour glass, with a
7 wide root radially innermost adjacent the bushing, a
8 wide top at the radially outermost part of the blade
9 that bears against the borehole wall, and a narrower
10 cutaway portion between the two to facilitate fluid
11 flow between the blades. This cutaway creates more
12 space for the fluid to pass between the blades, and
13 helps to avoid impedance of the fluid flow.

14

15 Typically the bushing can be formed from a rigid
16 material, such as hard rubber or metal. The sleeve
17 is typically formed from metal such as steel, alloy,
18 aluminium, etc.

19

20 The sleeve can have an annular body to fit around a
21 tubular or string of tubulars. The annular body can
22 have the vanes integrally formed with it, for
23 example by moulding the sleeve and vanes as a single
24 piece. In alternative (and preferred) embodiments,
25 the sleeve can have vane-receiving recesses therein
26 to receive and retain modular vanes, which can be
27 slotted in the recesses, and retained therein. This
28 has the advantage that several different sizes of
29 vanes can be used with a single sleeve.

30

1 Likewise, the blades on the bushing can be modular
2 and can be received within blade recesses in the
3 same manner.

4
5 The vanes can be curved or straight, and can lie
6 parallel to the axis, but in typical embodiments
7 they cross the axis of the sleeve so as to scoop the
8 fluid from the annulus. The lower end of the vane
9 is typically circumferentially spaced around the
10 sleeve from the upper end, typically in the
11 direction of rotation of the string, so where the
12 string rotates to the right (as is conventional in
13 most wells) the vanes are offset across the axis
14 from top right to bottom left, the opposite
15 configuration from the offset blades described
16 above.

17
18 In some embodiments the vanes are configured in a
19 sinusoidal "lazy-s" shape and this helps to agitate
20 the fluid surrounding the apparatus during rotation.
21 In other embodiments, they are disposed straight
22 across the axis.

23
24 The vanes can have concave surfaces to assist in the
25 scooping action, and typically the concave surfaces
26 can be provided in one side of the vane only,
27 typically on the side of the vane facing the
28 direction of rotation. The concave surface can be
29 regular and unchanging along the side of the vane,
30 but in some embodiments the side vane is shaped to
31 have more of a curve on its upper end than on its
32 lower end, so that as the fluid moves up the side of

1 the vane, the increasing curve of the concave
2 surface keeps the fluid close to the sleeve, where
3 most turbulence will be generated, thereby keeping
4 the cuttings in suspension for longer.

5
6 The or each vane can be provided with a notch cut
7 away from a radially outermost portion of the vane.
8 Several notches may be provided on each vane. The
9 notches can serve to introduce additional turbulence
10 or induce a vortex as the vane is rotated to agitate
11 drill cuttings and entrain them into the flow of
12 fluid up the annulus.

13
14 The invention also provides a drill cuttings
15 agitation assembly, comprising a tubular, a vane,
16 and at least two blades defining at least one fluid
17 conduit between adjacent blades, wherein the vane
18 and the blades are rotatable relative to one
19 another.

20
21 The invention also provides a method of agitating
22 drill fluid in an oil or gas well, the method
23 comprising passing the drill fluid past a vane
24 rotatable relative to at least two blades.

25
26 An embodiment of the invention will now be described
27 by way of example and with reference to the
28 accompanying drawings, in which:

29
30 Fig. 1 is a side view of apparatus according to
31 the present invention, mounted on a tubular;

1 Fig. 2 is a close up side view of the Fig 1
2 apparatus;
3 Fig. 3 is a side view of a sleeve of the Fig 1
4 apparatus;
5 Fig. 4 is a side view of a bushing of a bushing
6 of the Fig 1 apparatus;
7 Fig. 5 is a side view of a clamp of the Fig 1
8 apparatus;
9 Figs. 6 and 7 (respectively) plan and underside
10 views of the Fig 4 bushing;
11 Fig. 8 is a flat view of a bushing half shell;
12 Fig. 9 is a side view of a bushing blade;
13 Fig. 10 is a plan view of a sleeve;
14 Fig. 11 is a sectional view through a clamp;
15 Fig. 12 is an outer side view of a second
16 sleeve;
17 Fig. 13 is an inner side view of the second
18 sleeve;
19 Fig. 14 is a sectional view through the second
20 sleeve;
21 Fig. 15 is a perspective view of a modular vane
22 for the second sleeve;
23 Fig. 16 is an underneath view of the Fig 15
24 vane;
25 Fig. 17 is a plan view of the Fig 15 vane;
26 Fig. 18 is a side view of the same vane;
27 Fig. 19 is a side view of a second embodiment
28 of apparatus mounted on a tubular;
29 Fig. 20 is a sectional view from beneath the
30 Fig. 19 apparatus at point A;
31 Fig. 21 is a sectional view from beneath the
32 Fig. 19 apparatus at point B;

1 Fig. 22 is a plan of a vane;
2 Fig. 23 is a plan view of a second vane; and
3 Fig. 24 is a plan view of a vane having a cut-
4 out portion.

5
6 Referring now to the drawings, apparatus for
7 mobilising drill cuttings in a well comprises a
8 sleeve 5, a bushing 7 and a clamp 9. All of these
9 components are generally tubular, but are axially
10 divided into two separate leaves that are hinged
11 together. The leaves of the sleeve 5 are hinged at
12 three locations 5h, and its two leaves pivot around
13 those hinges to enable the sleeve 5 to be opened and
14 closed around a tubular T such as drill pipe or
15 casing. The two halves of the sleeve are locked
16 together by one or more bolts 5b at a position
17 diametrically opposite to the hinge 5h, so that the
18 sleeve 5 can be tightly fastened to the tubular T by
19 means of the bolts.

20
21 The hinges 5h are located on an upper part of the
22 sleeve 5, beneath which is a bearing region 6 having
23 a reduced outer diameter as compared with the
24 nominal diameter of the upper region. An annular
25 groove 6g is formed on the lower end of the bearing
26 region 6, and a shoulder 6s divides the upper and
27 bearing regions of the sleeve.

28
29 The bushing 7 is also formed as two separate leaves
30 that are connected together at diametrically opposed
31 positions by interlocking castellations and
32 connecting pins 7p, about which the two leaves can

1 pivot. The two leaves of the bushing 7 are
2 typically closed around the bearing region 6 of the
3 sleeve, at which point the leaves are connected
4 together by inserting the pins 7p into axially
5 aligned bores on the interlocking castellations to
6 close and lock the bushing 7, so that the bushing 7
7 is connected to the sleeve 5.

8
9 After the bushing 7 has been locked in place around
10 the bearing region 6 of the sleeve 5, the clamp 9 is
11 then placed around the lower end of the bearing
12 region 6, so that an annular lip on the internal
13 surface of the clamp 9 engages in the external
14 annular groove 6g on the lower part of the bearing
15 region 6. The clamp 9 is then closed and fastened
16 by means of bolts (not shown) in the same manner as
17 the bolts 5b that lock the sleeve closed around the
18 tubular T.

19
20 When thus assembled, the tightening of the bolts in
21 the sleeve 5 and the clamp 9 securely connects the
22 sleeve to the tubular, so that the two are
23 rotationally connected, and thus the sleeve rotates
24 with the tubular.

25
26 The bushing 7 is fixed to the bearing area 6 of the
27 sleeve, and is prevented from axial movement by the
28 shoulder 6s above it, and the clamp 9 below it;
29 however, the bushing 7 is free to rotate around its
30 axis relative to the sleeve and the clamp, and the
31 tolerance of the outer diameter of the bearing
32 region 6 and the inner diameter of the bushing 7 are

1 chosen to permit a degree of play between the two,
2 and allow rotation of the bushing 7 around the axis
3 of the sleeve 5.

4
5 The sleeve 5 has vanes 12 mounted on the upper large
6 diameter section. As best shown in Fig. 10, two
7 vanes 12 are mounted on each leaf of the sleeve, and
8 the vanes are spaced apart on the circumference of
9 the assembled sleeve 5 at equal distances, so that
10 the vanes 12 are arranged in diametrically opposed
11 pairs.

12
13 The vanes 12 have a generally sinusoidal "lazy-S"
14 shape with a lower scoop 12s, a generally axial mid-
15 region 12m, and an upper deflector portion 12d.

16
17 In side profile, the vanes 12 are generally arcuate
18 in the scoop and deflector regions, rising from the
19 plane of the sleeve 5 in a regular arc until a
20 plateau is reached at the mid-section 12m. Fig. 18
21 shows the side profile of a typical vane 12. The
22 vanes 12 project radially from the outer surface of
23 the sleeve 5, so as to create between adjacent vanes
24 12 a fluid path that is generally sinusoidal in
25 shape.

26
27 The bushing 7 has blades 15. Typically, there are
28 three blades arranged on each leaf of the bushing 7,
29 and typically these are circumferentially spaced at
30 equal distances, so that the blades 15 are arranged
31 in three diametrically opposed pairs, as best shown
32 in Figs. 6 and 7. Each blade 15 is arranged

1 generally parallel to the axis of the assembled
2 bushing 7, and in plan view, each blade 15 is in the
3 general shape of a foil or wing, as best shown in
4 Figs. 2 and 8. In detail, each blade 15 has a lower
5 end 15l that widens from the lowermost tip of the
6 blade to an apex 15a, from where it tapers through a
7 mid-section 15m, to an upper end 15u, and finally to
8 a slim point at the upper end. Shaping adjacent
9 blades like foils in this manner creates a flow path
10 between adjacent blades that rapidly narrows to a
11 throat at the level of the apex 15a of the blades,
12 and then gradually widens as the passage passes the
13 upper ends 15u of the blades.

14

15 As best shown in Fig. 9, the side profile of each
16 blade 15 rises from the plane of the bushing 7 at
17 the tips and is arcuate in the upper 15u and lower
18 15l ends, and forms a plateau in the mid-section
19 15m.

20

21 The nominal external diameter of the bushing 7 is
22 generally very close to the nominal external
23 diameter of the upper part of the sleeve 5, and also
24 matches that of the clamp 9, so that apart from the
25 vanes 12 and the blades 15, there are no upsets on
26 the outer surface of the apparatus.

27

28 The radial extent of the blades 15 typically exceeds
29 the radial extent of the vanes 12, so that the mid-
30 section 15m of the blades contacts the inner surface
31 of the bore in which the apparatus is deployed,

1 thereby spacing the vanes 12 from the inner surface
2 of the bore.

3
4 In preferred embodiments, the blades 15 are
5 integrally formed with the leaves of the bushing 7,
6 and in typical embodiments, the two leaves can be
7 cast or moulded each in a single piece with their
8 respective blades. Alternatively, the blades can be
9 formed separately and attached to the body of the
10 bushing 7 as required.

11
12 The vanes 12 can also be cast or moulded integrally
13 with the separate leaves of the sleeve, but in
14 preferred embodiments, the vanes 12 (and optionally
15 the blades 15) can be separately cast or otherwise
16 formed from the same or a different material, and
17 can be assembled with the sleeve prior to use in a
18 modular fashion.

19
20 One such arrangement is shown in Figs. 12 to 18.

21
22 In this embodiment, the sleeve 5 has a vane-
23 receiving portion 20, which comprises a region with
24 an increased inner diameter. Each vane 12 has a
25 base plate 12b attached to its radially innermost
26 face as shown in Fig. 15. The base plate 12b is
27 curved, with an outer diameter that matches the
28 inner diameter of a vane-receiving portion 20 of the
29 sleeve.

30
31 When the sleeve 5 is to be assembled with the
32 modular vanes 12, the radially outermost mid-portion

1 12m of each vane is offered to a vane-shaped slot 18
2 in the vane receiving portion 12, so that the mid-
3 portion 12m passes from the inner surface of the
4 sleeve 5 through the vane receiving slot 18, and
5 extends radially outward from the outer surface of
6 the sleeve 5. The curved radially outer face of the
7 base plate 12b of each vane 12 matches the inner
8 diameter of the vane receiving portion 20, and the
9 depth of each base plate 12b is chosen to match the
10 step between the nominal inner diameter of the
11 sleeve 5 and the nominal inner diameter of the vane
12 receiving portion 20, so that when the modular vanes
13 are assembled with the sleeve 5, the base plates 12b
14 are accommodated within the vane-receiving portion
15 20, and the inner diameter of the sleeve and base
16 place are contiguous. The assembled sleeve with
17 modular vanes 12 can then be clamped onto the
18 tubular T as previously described.

19
20 Modular vanes 12 give the advantage that worn vanes
21 can be replaced easily, and different sizes or
22 profiles of vanes 12 can be used with the same
23 sleeve body. Also, vanes of different materials or
24 properties can be provided on a generic sleeve 5,
25 and if desired, modular vanes 12 having different
26 characteristics can even be provided on the same
27 sleeve 5.

28
29 It will be appreciated that modular blades 15 can be
30 provided for the bushing 7 in the same way.

31

1 Typically the bushing 7 and blades 15 are formed
2 from a hard material such as a hard rubber or
3 plastic. Metals are also useful for the formation
4 of the bushing 7, and aluminium, zinc alloy, or
5 austempered ductile iron can be used for this
6 purpose.

7
8 The sleeve 5 and vanes 12 need not be formed from
9 the same material as the bushing 7 and blades 15,
10 and in preferred embodiments, metals or plastics can
11 be used for the vanes 12 and/or the sleeve 5.

12
13 In use, when the apparatus is clamped to a tubular T
14 such as a drill string that is being used to drill a
15 well, the device is typically deployed at regular
16 intervals along the bore, and can be used from a
17 position relatively close to the drill bit right up
18 to the top of the bore. The weight of the string T
19 typically forces the mid-portion 15m of the blades
20 15 against the inner surface of the wellbore, so
21 that the string is spaced away from the inner
22 surface of the wellbore by the radial extent of the
23 blades 15. Since the sleeve 5 is securely
24 rotationally fastened to the drill string T, the
25 sleeve 5 and hence the vanes 12 rotate in the
26 direction of arrow A in Fig. 1, ie clockwise when
27 viewed from the top of the string. However, since
28 the weight of the string is pressing the blades 15
29 against the inner surface of the wellbore, and since
30 the bushing 7 is rotatable on the bearing area 6,
31 the bushing 7 remains stationary relative to the

1 wellbore, and the sleeve and vanes 12 rotate
2 relative to the bushing 7 along with the string.
3

4 The radial dimensions of the blades 15 exceed those
5 of the vanes 12, and thus the vanes 12 are spaced
6 from the inner surface of the bore, and are not
7 impeded from rotating by contact with the inner
8 surface of the wellbore. The rotation of the vanes
9 12 and the speed of the string (typically 120-180
10 rpm with normal rotary drilling, but sometimes as
11 slow as 20 rpm with casing drilling) generates
12 turbulence in the drill fluid in the annulus between
13 the string and the wellbore. The sinusoidal
14 arrangement of the vanes 12 generates thrust in the
15 drill fluid in the region of the apparatus, and in
16 particular, the scoops 12s drive the drill fluid up
17 through the fluid passageways between adjacent
18 vanes, and the deflectors 12d accelerate it out of
19 the top of the fluid passage. In addition to
20 creating thrust in the fluid and pumping the fluid
21 from the lower end of the apparatus to the upper
22 end, this also creates turbulence in the fluid,
23 tending to break up clumps of drill cuttings, to
24 keep the fluid in a liquid phase.
25

26 The rapid rotation of the vanes 12 in the drill
27 fluid creates a pressure drop in the area between
28 the vanes 12 and the blades 15, which draws more
29 fluid up through the channels between adjacent
30 blades 15. As the fluid passes the apex 15a in the
31 channels between adjacent blades 15 on the
32 stationary bushing 7, it experiences a further

1 pressure drop created by the expansion in volume of
2 the fluid passageway as each blade narrows towards
3 its upper end. The pressure changes occurring as a
4 result of this speeds up fluid flow from the bit to
5 the surface, and also suspends cuttings in the
6 liquid phase, which makes it easier to return them
7 to surface.

8
9 An additional advantage of the non-rotating bushing
10 7 is that it reduces torque for rotation of the
11 string T within the hole, and the bearing surface
12 between the sleeve 5 and the bushing 7 is typically
13 lubricated by the drill fluid passing the apparatus.
14 In addition to this advantage, the smooth outer
15 surface of the blades 15, and particular the rounded
16 profile of the ends of the blades 15u and 15l, can
17 reduce drag while running in the hole, thereby also
18 reducing casing wear, and enhancing the penetration
19 of the drill bit. If the bushing 12 is manufactured
20 from materials having a low co-efficient of friction
21 then additional advantages in running in the hole
22 are also achieved. Notably, plastics, rubber and
23 zinc alloys give useful secondary advantages in this
24 respect.

25

26 The provision of the non-rotating bushing also
27 reduces drill string harmonics, and can help to
28 prevent differential sticking of the string.

29

30 Fig. 19 shows a further embodiment of apparatus for
31 mobilising drill cuttings in a well comprising a
32 sleeve 5', a bushing 7' and a clamp 9' similar to

1 that previously described for the first embodiment,
2 and assembled onto the string T in the same way.

3

4 The sleeve 5' has vanes 22 mounted on the upper
5 large diameter section. Only one vane 22 is mounted
6 on each leaf of the sleeve, and the vanes are spaced
7 apart on the circumference of the assembled sleeve
8 5' at equal distances, so that the vanes 22 are
9 diametrically opposed to one another.

10

11 The vanes 22 are generally straight, but are
12 attached to the sleeve 5' at an angle that is offset
13 with respect to the axis of the sleeve 5', from top
14 right to bottom left at around 5° wrt the axis.

15 Each vane 22 typically has a concave surface on one
16 side, typically that facing the direction of
17 rotation, as best seen in Fig. 20. The concave
18 surface typically acts as a scoop to create
19 turbulence in the fluid flowing up the annulus
20 between the sleeve 5' and the borehole. The radius
21 of curvature of the concave surface changes with the
22 axial position on the vane, as shown in Figs. 20 and
23 21, so that at the lower end of the blade (see B in
24 Fig. 19) the concave surface has a small curvature
25 with the radially outermost part of the blade being
26 nearly perpendicular to the tangent of the
27 circumference of the sleeve 5'; whereas at the upper
28 end of the blade (see A at Fig. 19) the radially
29 outermost part of the blade is more curved and
30 approaches a tangent to the circumference of the
31 sleeve 5'. This graduation in the radius of
32 curvature of the concave surface guides the fluid

1 flowing past the vane 22 towards the sleeve 5',
2 where turbulence and flow rates are highest, and
3 this keeps the cuttings in suspension for longer.

4
5 In some other embodiments of vanes, the change in
6 the radius of curvature is not required, and a
7 simple regular concave surface as shown in Figs. 22
8 and 23 will suffice. The vane shown in Fig. 22 can
9 be modified by cutting out a small portion towards
10 the centre of the radially outermost edge of the
11 vane. Such an embodiment of a vane 22' is shown in
12 Fig. 24. In an alternative embodiment, several
13 notches 90 may be provided on the vane 22'. The
14 notch 90 or notches can introduce additional
15 turbulence or create a vortex to assist in the pick-
16 up and agitation of drill cuttings to facilitate
17 their inclusion in the flow regime.

18
19 The bushing 7' has blades 25. Typically, there are
20 three blades arranged on each leaf of the bushing
21 7', and typically these are circumferentially spaced
22 at equal distances, so that the blades 25 are
23 arranged in three diametrically opposed pairs. Each
24 blade 25 is offset at a 5° angle wrt the axis of the
25 assembled bushing 7', from top left to bottom right,
26 in an opposite configuration to the offset of the
27 vanes 22.

28
29 In side profile, as shown in Fig. 19, each blade 25
30 comprises a central plateau region and radially
31 lower ends. The width of the blades are consistent

1 throughout their length unlike the earlier
2 embodiments.

3

4 The nominal external diameter of the bushing 7' is
5 generally very close to the nominal external
6 diameter of the upper part of the sleeve 5', and
7 also matches that of the clamp 9', so that apart
8 from the vanes 22 and the blades 25, there are no
9 upsets on the outer surface of the apparatus.

10

11 The radial extent of the blades 25 typically exceeds
12 the radial extent of the vanes 22, so that the
13 plateau sections of the blades contact the inner
14 surface of the bore in which the apparatus is
15 deployed, thereby spacing the vanes 22 from the
16 inner surface of the bore.

17

18 The blades 25 have profiled cross sections (i.e.
19 end-on views) in the form of an hour glass as best
20 shown in Figs. 20 and 21, with a wide root radially
21 innermost adjacent the bushing, a wide top at the
22 radially outermost plateau of the blade that bears
23 against the borehole wall, and a narrower cutaway
24 portion radially between the two to facilitate fluid
25 flow between the blades. This cutaway creates more
26 space for the fluid to pass between the blades, and
27 helps to avoid impedance of the fluid flow.

28

29 In use the operation of the second embodiment is
30 similar to the first, but the vanes 22 keep the
31 drill fluid and cuttings close to the wall of the
32 sleeve as the scoops drive the drill fluid up

1 through the fluid passageways between adjacent
2 vanes. In addition to creating thrust in the fluid
3 and pumping the fluid from the lower end of the
4 apparatus to the upper end, this also creates
5 turbulence in the fluid, tending to break up clumps
6 of drill cuttings, to keep the fluid in a liquid
7 phase.

8
9 Modifications and improvements can be incorporated
10 without departing from the scope of the invention.

11
12